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(54) Molding roll, method for manufacturing it, and apparatus for forming substrate sheet for optical recording medium.

(57) The present invention provides a molding roll having a relief pattern on its surface. The molding roll comprises a roll base and a stamper fixed on the peripheral surface of the roll base, the stamper being roll-shaped and seamless. Using the molding roll, substrates for optical recording media can be produced successively in which fine patterns corresponding to information are transferred precisely.

FIG.3A

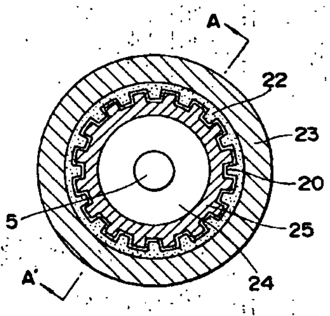

FIG.3B

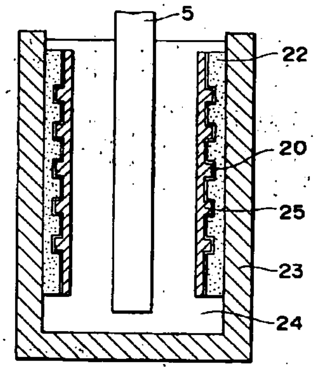

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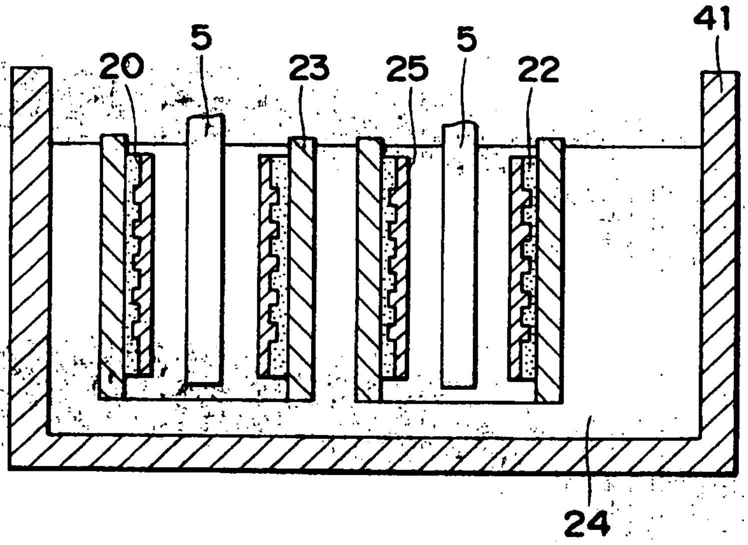
FIG.4



BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to a molding roll for continuously molding holograms and hight-density information recording media such as optical discs and optical cards which can record and reproduce information by changing optical characteristics such as reflectance with light such as a laser beam, and it also relates to a method for manufacturing the molding roll.

Related Background Art

Heretofore, as a method for continuously manufacturing molded articles having a fine pattern of micron order or submicron order on the surfaces thereof, for example, substrates for optical recording media, holograms and the like, there has been, for example, a method using a molding roll as described in International Publication No. W088/03311.

This type of molding roll can be manufactured by the following conventional known methods:

(1) A method which comprises mechanically directly cutting the surface of the roller by a diamond bite or the like,

(2) a method which comprises coating the roller with a photosensitive material such as a photoresist, exposing it to light by the use of a laser and a photo-mask to form a pattern thereon, and then forming a relief pattern on the roller by using this pattern and by etching or lift-off, and

(3) a method which comprises first forming a relief pattern on a plate, and then winding the plate onto the roller.

However, when the relief pattern is fine, the above-mentioned conventional methods have the following drawbacks.

First of all, in the method which comprises mechanically directly cutting the surface of the roller by a diamond bite or the like in the paragraph (1), the limitation of the fineness of the pattern depends upon the size of a cutting blade, the accuracy of feed pitch and the rotary accuracy of the roller (jitter, vibratory motion and the like).

For example, in the cases of pregrooves and preformats which are transferred to the substrates of optical discs and optical cards which are now investigated as information recording media, the fine pattern is required which has a size of about 0.5 to 5 μm and a depth of 50 to 5000 Å. However, the mechanical method of the paragraph (1) can scarcely provide the sufficiently satisfactory accuracy.

Next, in the method which comprises coating the roller with the photosensitive material and then finely patterning on the roller in the paragraph (2), it is difficult to provide the accuracy at the times of (i) coating the roller with the uniform photoresist, (ii) exposing the pattern to light on the roller and (iii) patterning uniformly on the roller by etching or the like. In order to obtain the satisfactory accuracy, large apparatuses are required and considerable facility investment is necessary.

Moreover, in the method which comprises fixedly winding the plate stamper onto the roll base in the paragraph (3), it is necessary to meet durability at a high temperature (e.g., 300°C or less in the case of polycarbonate) and under a high pressure (e.g., 30 kg/cm^2 or less) during the molding of a resin. For this purpose, various fixtures are required and a fixing manner is often complex. In addition, the treatment of a step between the edge face of the stamper and the surface of the roll base is also troublesome.

SUMMARY OF THE INVENTION

The present invention has been achieved to solve the above-mentioned problems of conventional techniques, and an object of the present invention is to provide a molding roll which has a highly accurate and fine relief pattern and which does not transfer an unnecessary step.

Another object of the present invention is to provide a method for manufacturing a molding roll which has a highly accurate and fine relief pattern and which does not transfer an unnecessary step without using expensive facilities.

That is, a molding roll of the present invention is a molding roll having a relief pattern (which is comprised of raised arears and engraved areas) on the peripheral surface thereof which comprises a roll base and a stamper fixed on the peripheral surface of the roll base, said stamper being roll-shaped and seamless.

A method for manufacturing a molding roll according to the present invention is a method for manufacturing a molding roll having a relief pattern on the peripheral surface thereof and comprising a roll base and a roll-shaped and seamless stamper fixed on the peripheral surface of the roll base, said method being characterized by comprising the steps of;

a first step of installing a flexible master having a pattern corresponding to the relief pattern of the molding roll on the surface thereof in a cylindrical mold so that the back surface of the flexible master may be brought into contact with the inside peripheral surface of the cylindrical mold,

a second step of applying electroforming to the surface of the flexible master to form a roll-shaped stamper thereon,

a third step of releasing the flexible master having the formed roll-shaped stamper from the cylindrical mold, and then separating the roll-like stamper from the flexible master,

and a step of processing the roll-shaped stamper into the molding roll.

A method for manufacturing a molding roll for molding substrate sheets for optical cards according to the present invention is a method for manufacturing a molding roll for molding substrate sheets for optical cards having preformat patterns corresponding to striped pregrooves and prepits on the peripheral surface thereof and comprising a roll base and a roll-shaped and seamless stamper fixed on the peripheral surface of the roll base, said method being characterized by comprising the steps of:

a first step of installing a flexible master having a pattern corresponding to the preformat pattern on the surface thereof in a cylindrical mold so that the back surface of the flexible master may be brought into contact with the inside peripheral surface of the cylindrical mold,

a second step of applying electroforming to the surface of the flexible master to form a roll-shaped stamper,

a third step of releasing the flexible master having the formed roll-shaped stamper from the cylindrical mold, and then separating the roll-shaped stamper from the flexible master,

and a step of processing the roll-shaped stamper into the molding roll.

An apparatus for manufacturing substrate sheets for optical recording media according to the present invention which comprises a means for melting and extruding a resin to mold a resin sheet, a molding roll for pressing the resin sheet to transfer a preformat pattern to the surface of the resin sheet, and a mirror roll disposed in the face of the molding roll, said molding roll being provided with a roll base and a roll-shaped and seamless stamper fixed on the peripheral surface of the roll base.

An apparatus for manufacturing substrate sheets for optical recording media according to the present invention by which a preformat pattern of a molding roll having the preformat pattern on the peripheral surface thereof is transferred to continuously manufacture substrate sheets for optical recording media, said apparatus being characterized by comprising:

the molding roll being rotated in a predetermined direction,

a sheet feed means for feeding light-permeable substrate sheets,

a means for forming a photocurable resin composition layer on the peripheral surface of the molding roll,

a means for pressing the photocurable resin composition layer on the peripheral surface of the molding roll against the substrate sheet,

a means which is disposed at a position apart from the pressing position in the rotational direction of the molding roll and which irradiates the photocurable resin composition layer through the substrate sheet with light, and

a means for releasing from the molding roll the resin layer which is integrated with the substrate sheet and to which the preformat pattern is transferred, by irradiation with light from the irradiation means,

said molding roll being provided with a roll base and a roll-shaped and seamless stamper fixed on the peripheral surface of the roll base.

That is, according to the present invention, a roll-shaped stamper having on its surface a highly accurate and fine relief pattern can be manufactured directly in a roll form by installing a flexible master with a pattern corresponding to a relief pattern on the inside peripheral surface of a cylindrical mold, forming a film on the flexible substrate by means of electroforming, and then peeling the flexible substrate from the electroforming film. This manufacturing operation can be achieved by a conventional inexpensive apparatus. The roll-shaped stamper thus prepared is fixed on a roll base, thereby easily obtaining a seamless molding roll.

BRIEF DESCRIPTION OF THE DRAWINGS

Figs. 1A and 1B are schematic sectional views of a molding roll of the present invention.

Fig. 2A is a schematic sectional view of a flexible master used for manufacturing the molding roll of the present invention.

Fig. 2B is a schematic sectional view of a cylindrical mold in which the flexible master is installed.

Figs. 3A and 3B are schematic views of the cylindrical mold shown in Fig. 2B having an electroforming-film deposited on the cyclindrical mold surface.

Fig. 4 is a schematic view illustrating another embodiment of an electroforming method in manufacturing the molding roll of the present invention.

Figs. 5A, 5B and 5C in series illustrate one embodiment of manufacturing steps of a flexible master of the present invention.

Fig. 6 is a schematic view illustrating a step in which the molding roll is manufactured by the use of a roll-shaped stamper.

Figs. 7A and 7B show schematic sectional views of the molding roll in which the inside peripheral surface of the roll-shaped stamper is tapered and then detachably fitted to a roll base, Fig. 7A being a schematic section illustrating a step for forming the molding roll and Fig. 7B being a schematic section of the molding roll.

Fig. 8 is an illustrative view of the preformat of an optical card.

Fig. 9 is an enlarged view of the preformat pattern of the flexible master.

Fig. 10 is a schematic view of the flexible master along the line A-A′ in Fig. 9 which is disposed in parallel with the peripheral direction of the inside peripheral surface of a cylindrical mold.

Fig. 11 is a schematic view of the flexible master along the line B-B′ in Fig. 9 which is disposed in parallel with the peripheral direction of the inside peripheral surface of the cylindrical mold.

Fig. 12 is a schematic sectional view of the cylindrical mold in Fig. 10.

Fig. 13 is a schematic view of a preformat pattern portion in another embodiment of the cylindrical mold having the mounted flexible master which is used in manufacturing the molding roll of the present invention.

Figs. 14A and 14B are schematic views of a preformat pattern portion in still another embodiment of the cylindrical mold having the mounted flexible master which is used in manufacturing the molding roll of the present invention.

Fig. 15 is a schematic sectional view of an apparatus for manufacturing substrate sheets for optical recording media empolying the molding roll of the present invention.

Fig. 16 is a schematic sectional view showing another embodiment of an apparatus for manufacturing substrate sheets for optical recording media employing the molding roll of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

The present invention will be described in detail in reference to drawings.

Fig. 1A is a schematic section of a molding roll 1 of the present invention in a vertical direction to the peripheral surface thereof, and Fig. 1B is a schematic section of the molding roll 1 in a parallel direction to the peripheral surface thereof.

In Figs. 1A and 1B, reference numeral 2 is a roll-shaped stamper, numeral 3 is an adhesive layer, and 4 is a roll base which is a reinforcing material.

Figs. 2A and 2B and Figs. 3A and 3B are schematic views illustrating embodiments of a manufacturing method of the molding roll according to the present invention. That is, Fig. 2A shows a flexible master 22 having on the surface thereof a pattern 21 corresponding to a fine pattern which will be formed on the peripheral surface of a roll stamper 2, on the surface of which an electroconductive film 20 is formed. As shown in Fig. 2B, the flexible master 22 is disposed in a cylindrical mold 23 so that the back surface of the flexible master 22 may be brought into contact with the inside peripheral surface of the cylindrical mold 23. Next, this cylindrical mold 23 is filled with an electroforming liquid 24, and an anode electrode 5 is dipped in the electrolyte, as shown in Fig. 3A and Fig. 3B. In the cylindrical mold, electroforming is carried out at a constant current density between a cathode which is the electroconductive film 20 on the flexible master 22 and an anode electrode 5.

When an electroformed film 25 has reached a predetermined thickness, the electroforming is stopped, and the flexible master 22 having the electroforming film 25 is then released from the cylindrical mold 23. After washing with water, the electroforming film 25 is peeled from the flexible substrate 22 to obtain the cylindrical (roll-shaped) stamper 2.

In the last place, the roll-shaped stamper is reinforced with a roll base to obtain the molding roll shown in Fig. 1.

In the present invention, the flexible master 22 can be closely fixed on the inside peripheral surface of the cylindrical mold 23, and the inside surface of the flexible master 22 is preferably such as to meet the outer diameter accuracy (such as roundness) of the roll stamper to be manufactured. Preferably usable examples of the material of the flexible master 22 include thin films and sheets of synthetic resins such as polyester, polyolefin, polyamide and polyimide, metals and ceramics. The thickness of the flexible master 22 is in the range of 1.0 x 10^{-3} to 10 mm, preferably 3.0 x 10^{-3} to 5 mm, and it is preferred that the scatter of the thickness is ±10% of the thickness and does not exceed 50 µm.

Furthermore, the flexible master has the fine relief pattern 21 formed on its surface. As a process for forming the flexible master 22, the following processes can be preferably utilized.

(1) A process in which a thermoplastic resin is used, and the fine relief pattern is thermally formed on its surface by injection molding or compression molding.

(2) A process in which a photosensitive resin layer such as a 2P material is formed on a substrate for the flexible master, and the surface of the stamper is then transferred thereto by the so-called 2P method to form the relief pattern thereon.

(3) A pattern mask is formed on the substrate for the flexible master by the Hotorin process, and this mask is used to form the relief pattern by etching or lift-off. In the former case, the substrate itself is etched, and in the latter case, the pattern layer is formed on the substrate, thereby forming the relief pattern.

(4) A method using a casting technique in which as shown in Figs. 5A, 5B and 5C, a liquid resin is poured into a casting cell 51 [Fig. 5B], followed by polymerizing, whereby the flexible master 22 can be directly prepared.

(5) A method in which the relief pattern is directly formed on the substrate for the flexible master or a layer provided thereon by a mechanical cutting means.

In the case of the roll stamper for molding the substrate for the optical recording medium, examples of the relief pattern include spiral patterns, concentric circle patterns and striped patterns corresponding to tracking grooves of optical discs and optical cards having a width of 1 to 4 µm, a pitch of 1 to 20 µm and a depth of about 200 to about 5000 Å as well as patterns corresponding to address pits having a width of 0.6 to 10 µm, a length of 0.6 to 20 µm and a depth of about 200 to about 5000 Å.

The electroconductive film 20 is formed on the surface, which is on the side a fine relief pattern is formed, of the flexible master formed in the above-mentioned manner. The electroconductive film formation may be carried out when the flexible master is in the form of a plate or is present in the cylindrical mold.

The electroconductive film 20 can be formed by a vacuum film formation technique such as sputtering or vapor deposition or electroless plating of a conductive metal such as nickel, and this film 20 which functions as a cathode in the electroforming step is connected to a minus side of an electric source.

This flexible master 22 having the thus formed fine relief pattern is closely fixed on the inside surface of the cylindrical mold, and this close fixing state has influence upon the accuracy of the outer diameter of the molding roll.

Therefore, in order to obtain this close fixing state stably, a means for vacuum-chucking the flexible master in the cylindrical mold may be provided, or alternatively the flexible master may be temporarily fixed by screws or the like [Fig. 2B].

The cylindrical mold, in which the flexible master having the fine relief pattern with the electroconductive film 20 is installed on the inside peripheral surface thereof, is then dipped in an electrolysis tank. Next, the electroconductive film 20 is utilized as the cathode, and the electroforming is then carried out at a given current density between the cathode and the anode electrode 5.

Figs. 3A and 3B show an embodiment in which the cylindrical mold equipped with the substrate constitutes one electrolysis tank, but the cylindrical mold may be dipped in the large electrolysis tank. Particularly, the latter has advantages that many cylindrical molds can be treated simultaneously and some of them can be taken out during the electroforming to be submitted easily for inspection or processing. Fig. 4 shows an embodiment in which the two cylindrical molds 23 are simultaneously dipped and electroformed in the electrolyte 24 in the electrolysis tank 41.

At the time when the electroforming film 25 has reached a predetermined thickness, the electroforming is brought to an end, and the flexible master 22 having the electroforming film 25 is taken off from the cylindrical mold 23 and the electroforming film 25 is then peeled from the flexible substrate 22, thereby obtaining the roll stamper.

The thickness of the electroforming film can be controlled basically by regulating quantity of electricity, i.e., current x time, but in fact, it is important to control the deformation and the peeling of the film which are attributed to the stress of the electroforming film caused by the unevenness of current density and film formation velocity.

Electroforming is carried out with a current density of 3 to 5 A/dm^2 using a constant-current source or a constant-voltage source. The temperature of the electroforming liquid is also one of the important factors for determining the quality of the film and the velocity of the film formation, and usually it is in the range of 40 to 60°C. When a temperature in this range is employed and the liquid is sufficiently stirred during the electroforming step, the stable film having no unevenness can be formed.

In forming the film, at an early stage (until about 0.1% of the final thickness of the electroforming film), electroforming is carried out with a current density (e.g., about 3 A/cm^2) at the low film formation velocity, and then, with a raised current density (e.g., about 5 A/dm^2), accomplished at a high film formation velocity.

According to the above-mentioned procedure, the electroforming film having a predetermined thickness is formed so that the residual stress may not remain at the time of the film formation, and the electroformed film and the flexible substrate are then released from the cylindrical mold. Afterward, the flexible substrate is peeled from the electroforming film, whereby the good roll stamper having neither distortion nor deformation is obtained.

The roll stamper obtained by the above-mentioned procedure can be used as the molding roll by itself, and a mechanical reinforcement may be given in accordance with the thickness of the electroformed film. Examples of the reinforcement technique include a manner in which if necessary, the inside peripheral surface of the roll-shaped electroforming film is polished, and the roll-shaped stamper is fixed on the roll base by an organic or an inorganic adhesive 61 or screws, as shown in Figs. 1A and 1B, and another manner in which the inside peripheral surface of the electroformed film is polished in the form of a taper, and the electroforming film is then detachably fitted on the previously tapered roll base, as shown in Fig. 7B.

The manufacture of the molding roll 1 by the use of the roll stamper is preferably carried out after completion of the electroforming and before the release of the roll stamper from the cylindrical mold.

That is, in either case of the above-mentioned reinforcing manners, the axis and the rotary surface of the molding roll are required to have high accuracy, and therefore vibratory motion and rotary unevenness of the axis as well as the movement of the rotary surface must be sufficiently controlled. In order to meet this requirement, the operations for manufacturing the molding roll, i.e., the polishing of the inside peripheral surface of the electroforming film and the fixing and fitting of the roll base are carried out utilizing, as a processing frame and a processing foundation (fundamental surface), the cylindrical mold in which the flexible master is installed, whereby the high processing accuracy can be obtained and thus the high-quality molding roll can be manufactured.

In the maintenance of the stamper surface of the molding roll, for example, it is required to remove soils on the surface which are involved in the resin molding step. In the case of such a molding roll as shown in Figs. 7A and 7B, the roll-shaped stamper 2 can be detachably fitted on the roll base 71, so that the maintenance of the molding roll can be achieved only by exchanging the roll-like stamper.

The inside peripheral surface of the roll stamper according to the present invention can be polished in a usual manner such as lathe processing.

The cylindrical mold which can be used in the present invention preferably has satisfactory stiffness, uniform wall thickness and excellent surface accuracy on inside and outside peripheral surfaces. The inner diameter of the cylindrical mold 23 determines the outer diameter of the roll-shaped stamper, and processing accuracy such as the roundness of the inside surface of the cylindrical mold is directly connected with the accuracy of the outer diameter of the roll-shaped stamper. Taking these points into consideration, the cylindrical mold preferably is excellent in the roundness of the inside and outside peripheries, and such a cylindrical mold can be formed from a metal, ceramics or a synthetic resin inclusive of a reinforced plastic such as FRP.

In the case that the molding roll for molding substrates for optical cards which has the relief pattern corresponding to striped pregrooves and prepits is manufactured by installing the flexible master in the cylindrical mold so that the pregroove pattern may be arranged in parallel with the peripheral direction of the cylindrical mold, the molding roll can be obtained which can mold the substrates for optical cards having high accuracy and less defects such as breakage and peeling.

This reason will be described as follows:

Fig. 8 shows a plan view of the substrate for the optical card. As shown in Fig. 8, the optical card is provided with a preformat having a size of 85 mm x 54 mm and a width of 31 mm in parallel with a longitudinal direction. Fig. 9 is an enlarged view showing a preformat pattern including a pattern corresponding to the pregrooves of the flexible master for molding the optical card shown in Fig. 8. On the track in Fig. 9, there are shown a pattern 91 corresponding to the pregrooves for AT and another pattern 92 corresponding to prepits. Figs. 10 and 11 show sectional views along the lines A-A′ and B-B′ of the relief pattern of the above-mentioned track graven on the flexible master, respectively.

Now, when the flexible master having the preformat pattern shown in Fig. 9 is installed along the inside periphery of the cylindrical mold, the following results can be obtained by comparing (1) a case where the line A - A′ is placed in parallel with the peripheral direction D with (2) another case where the line B - B′ is placed in parallel with the peripheral direction D. That is, in the case of (1) (Fig. 10), with regard to the width of the pattern 91 corresponding to the pregrooves and the side C of the pattern 92 corresponding to the prepits, the length a_0 of an opening is smaller than the length b_0 of a bottom. On the other hand, in the case of (2) (Fig. 11), such a phenomenon does not occur on the pattern 91 corresponding to the grooves, and only with regard to the side C of the pattern 92 corresponding to the pits, the opening is smaller than the bottom.

As a result, in the roll stamper formed by the process of (2), the sectional shape of the convex pattern for the formation of the pregrooves does not take such a reverse taper shape that the width of the pattern increases toward its tip. Therefore, when this molding roll is used so as to continuously form the substrates for the optical cards, neither breakage nor peeling occurs in the vicinity of the pregrooves of the substrates, so that the substrates for the optical cards having less defects can be obtained.

The sectional shape of the pattern 92 corresponding to the prepits is preferably formed so that its surface f may have an angle θ_0 to a base, and in such a case, when the pattern 92 is installed in the cylindrical mold, the opening of the pattern 92 is equal to or larger than the base thereof. At this time, the angle θ_0 is 10° to 85°, preferably 25° to 83°, more preferably from 30° to 80°.

In the case that the pattern 91 and 92 of the flexible master are formed as shown in Fig. 14 and the pattern 91 corresponding to the pregrooves is formed so that the vertically sectional shape of the pattern 91 may be grooves (having an angle of θ_1 to the base) and so that surfaces e and f of the pattern 91 corresponding to the prepits may have angles of θ_2 and θ_3, respectively, the molding roll can be prepared which can provide the substrates for the optical cards having less defective and high accuracy without restricting the direction of the preformat when the flexible master 22 having the preformat is installed in the cylindrical mold 23.

At this time, values of θ_1, θ_2 and θ_3 are from 10° to 85°, preferably from 25° to 83°, more preferably from 30° to 80°. The flexible master having the above-mentioned fine and accurate preformat pattern can preferably be manufactured by the aforesaid casting method which is excellent in transfer properties of a matrix. It can be achieved by a method described in Japanese Patent Laid-open No. 1-275018 to incline the wall portions of the patterns 91 and 92 corresponding to the above-mentioned pregrooves and prepits. For example, the composition of a chromium layer formed on a glass original plate is continuously changed at the time of the formation of the original plate to prepare a matrix, and the flexible master is then molded by casting and by the use of the matrix.

In the present invention, when the roll base 4 is used as a reinforcing member for the roll-shaped stamper 2, the roll base preferably has high hardness and good thermal conductivity and permits easily achieving the mirror processing of its peripheral surface, and examples of the material of the roll base include steel, chromium steel, aluminum and steel for molds (maraging steel). The roll,base peripheral surface is preferably processed so that its surface accuracy may be substantially equal to or higher than the surface accuracy of the substrate for the optical recording medium to be molded, and for example, the surface accuracy of the roll base peripheral surface is 1 µm or less, preferably 0.5 µm or less, more preferably 0.2 µm or less.

If necessary, the roll base may be coated with a hard film such as titanium nitride or treated with plating such as chromium plating.

The diameter of the roll base 11 depends upon its application, but when the roll base is used as the roll base for the molding of the substrates for the optical cards, the diameter is set to 100 to 500 mm, preferably 200 to about 400 mm.

Next, an apparatus and a method for manufacturing a substrate sheet for optical recording medium by the use of the molding roll of the present invention will be described in detail.

That is, in Fig. 15, resin pellets thrown into the extruder 151 are first heated, melted and extruded in a barrel of the extruder 151, pressed by a screw in a molding machine, and then molded into a sheet shape by the T-die 152. The T-die is preferably disposed so that the resin sheet may be extruded between the molding roll 1 and the mirror roll 154, because such a disposition permits transferring the preformat pattern precisely.

Next, the molded resin sheet extruded from the T-die is pressed between the molding roll 1 and the mirror roll to transfer the preformat pattern. At this time, it is preferred that the molded resin sheet 135 is extremely close to a melting state, since the resin can be sufficiently pressed into recesses on the stamper to transfer the fine pattern precisely. Accordingly, the temperature of the T-die preferably is as high as possible, so long as the resin does not decompose, and it is preferably in the range of the glass transition temperature (hereinafter abbreviated to "Tg") of the molded resin + 110°C to Tg + 200°C, particularly Tg + 130°C to Tg + 190°C. For example, in the case of a polycarbonate resin, the temperature of the T-die is 260 to 340°C, preferably 280 to 330°C, more preferably 290 to 320°C.

If the resin sheet is cooled between the T-die 152 and the molding roll 1, the preformat pattern is not sufficiently transferred and the double refraction tends to occur. Therefore, the distance between the T-die 32 and the pressing point of the molding roll 1 and the first mirror roll 154 is 20 cm or less, preferably 15 cm or less, more preferably 10 cm or less, and the temperature of an ambient atmosphere therebetween preferably is 60°C or more.

In order to precisely extrude the resin sheet toward the pressing point, the constitution of vertical extrusion is preferably taken as shown in Fig. 15 in which the pressing point is disposed vertically under the T-die. This reason is that since the resin is nearly in the melting state, the vertical extrusion permits extruding the resin toward the pressing point more accurately than horizontal extrusion.

Surface temperatures of the molding roll 1 and the mirror rolls 154, 155 depend upon the kind of resin to be used. For example, in the case that polycarbonate is used, the temperature of the molding roll 1 is usually set to 110-145°C considering the heat deformation temperature of the polycarbonate, that of the first mirror roll is set to 90-135°C, and that of the third mirror roll is set to 120-150°C. In the case that amorphous polyolefin is used, the temperature of the molding roll 1 is set to 120-145°C, that of the first mirror roll is set to 100-135°C, and that of the third mirror roll is set to 120-150°C. According to the present invention, even if the set temperature fluctuates in this range, the transfer accuracy of the preformat pattern and the double refraction do not largely fluctuate, so that the homogeneous and excellent substrate sheet for the optical recording medium can be formed. The temperatures of these rolls can be controlled, for example, by heating them with a heater incorporated in the rolls or by circulating a hot medium to the central portions of these rolls.

Fig. 16 is an illustrative view of another apparatus and method for manufacturing a substrate sheet for the optical recording medium by the use of the molding roll according to the present invention. In Fig. 16, reference numeral 161 is a feed tank for a photocurable resin such as an ultraviolet or an electron beam curable resin, and a resin layer 162 is formed on the surface of the molding roll by an ink feed roll 163. Next, the resin layer 162 on the molding roll is pressed against a sheet substrate 164 by a nip roll 167. Then, the resin layer 162 is irradiated with ultraviolet rays or electron beams by an ultraviolet or an electron beam irradiation means 168 to cure the photocurable resin layer and integrate the resin layer with the substrate sheet. Afterward, the substrate sheet having the resin layer is released from the molding roll 1 by using a releasing roll 169, thereby obtaining the substrate sheet for the optical recording medium.

In the present invention, as the photocurable resin, there can be used photopolymerizable prepolymers, photopolymerizable monomer and usual photocurable resins containing a photo-initiator. Usable examples of the photopolymerizable prepolymers include acrylates such as unsaturated polyesters, epoxy acrylates, urethane acrylates and polyether acrylates, and usable examples of the photopolymerizable monomer include monofunctional monomers such as lauryl acrylate, 2-ethylhexyl acrylate, 1,6-hexanediol monoacrylate and dicyclopentadiene acrylate as well as polyfunctional monomers such as dicyclopentenyl acrylate, 1,3-butanediol diacrylate, polyethylene glycol diacrylate, pentaerythritol triacrylate. In addition, examples of the photo-initiator include usually usable photo-initiators such as benzophenone, benzoin and its derivatives, benzoin ether and benzyldimethyl ketal.

The photocurable resin preferably has good adhesive properties to the sheet substrate 1, and its example is a usual photocurable adhesive. Typical examples of the photocurable adhesive include urethane acrylates, epoxy acrylates and polyester acrylates. The coating film thickness of the photocurable resin is 50 μm or less, preferably 20 μm or less, so as to inhibit the substrate for the optical recording medium from warping owing to the curing shrinkage of the photocurable resin layer.

This thickness of the film can be adjusted by a blade 165. In the present invention, no particular restriction is put on the coating manner of the photocurable resin, and it can be selected from known coating manners such as roll coating and bar coating in compliance with the viscosity, the coating film thickness and the like of the coating resin.

In the present invention, the feed rate of the sheet substrate 164 is from 0.02 m/minute to 7 m/minute, particularly from 0.05 m/minute to 5 m/minute from the viewpoints of the productivity of the substrates for the optical recording media, the entrainment prevention of air bubbles and the improvement of adhesive properties.

The material of the sheet substrate 164 of the present invention preferably is transparent to recording/reproducing light and has large mechanical strength and less double refraction and hygroscopicity. Preferable examples of such a material include polycarbonate resins, acrylic resins, epoxy resins, polyester resins and polyolefin resins, and above all, the polycarbonate resins, acrylic resins and polyolefin resins can be suitably used.

The thickness of the sheet substrate is 2.0 mm or less, preferably 0.2 to 1.4 mm. That is, the sheet substrate having the thickness in this range can exclude the influence of dust and the like on the surface of the substrate, when irradiation is made with recording light or reproducing light from the side of the substrate.

As described above, according to the present invention, a seamless molding roll having no step on its surface can easily be manufactured. The present invention has advantages such that (1) expensive facilities is not required, (2) high accuracy of the fine relief pattern is securised and (3) the shape of the stamper is cylindrical.

According to the present invention, a flexible master having an electroforming film is brought into close contact with the inside peripheral surface of a cylindrical mold, and a molding roll is prepared therefrom while the state of the close contact is maintained. Therefore, the manufacture of the molding roll can be achieved utilizing the cylindrical mold as foundation, so that it is possible to obtain the molding roll having high processing accuracy.

Moreover, according to the present invention, there can be obtained, at a low cost, the molding roll for molding substrate sheets for optical recording media which can continuously transfer a preformat pattern with high accuracy.

Next, the present invention will be described in more detail in reference to examples.

Example 1

In the first place, a flexible master was manufactured in the manner shown in Figs. 5A, 5B and 5C as follows.

First, a matrix 52 which would be used in a casting cell 51 was prepared. That is, a chromium film having a thickness of 3000 Å was vacuum-deposited on a mirror-polished glass plate having a thickness of 2.3 mm. Afterward, on this chromium film, a positive photoresist (trade name AZ-1350; Hoechst Japan Inc.) having a tickness of 1000 Å was formed by a spin coating process.

Next, this photoresist layer was exposed to light through a mask to print a pattern corresponding to a preformat for optical cards thereon, and development was then carried out with a developing solution (trade name AZ-312; Hoechst Japan Inc.) to form a resist pattern. Afterward, the exposed portions of the chromium film were etched with 6 N hydiochloric acid. After sufficient washing and drying, the remaining photoresist was incinerated and removed by the use of an oxygen-plasma incineration method, whereby the matrix was obtained.

In this example, a preformat for the optical cards was composed of 2583 pregrooves having a width of 3 µm, a pitch of 12 µm and a depth of 2700 Å and prepits having a width of 3 µm, a pitch of 12 µm, a depth of 2700 Å and a length of 6 µm which were formed on lands between the grooves, and the sectional shape of the pregrooves and the prepits in a vertical direction to them was rectangular.

Next, the casting cell shown in Fig. 5A was constructed using the matrix 52, and a liquid resin having the following composition was poured into a cavity. Afterward, the resin was heated at 120 °C for 2 hours and then slowly cooled over 10 hours to cure the same, and it was then released therefrom, thereby obtaining the flexible master having a thickness of 0.5 mm.

Composition of Liquid Resin

Methyl methacrylate	70 parts by weight
Tertiarybutyl methacrylate	25 parts by weight
Polyethylene glycol dimethacrylate (molecular weight 620)	5 parts by weight

On the surface of this flexible master on which the preformat patter was formed, a nickel film of 500 Å in thickness was formed by an electroless plating process to make the above-mentioned surface electroconductive. Next, this flexible master was fixed by screws in a stainless steel cylindrical mold having an inner diameter of 200 mm, an outer diameter of 220 mm and an inside and an outside peripheral surface accuracy of 0.2 so that the pregroove pattern might be arranged in parallel with the peripheral direction of the cylindrical mold as shown in Fig. 11 and so that the back surface of the flexible master might be brought into close contact with the inside peripheral surface of the cylindrical mold. Afterward, as shown in Fig. 4, the cylindrical mold was dipped in an electroforming tank, and a nickel anode electrode 5 was installed in the center of the cylindrical mold and electroforming was then carried out utilizing the nickel film on the surface of the flexible master as a cathode for 6 hours to deposit a nickel film having a thickness of 200 µm.

The composition of an electroforming liquid was as follows:

Nickel sulfamate	600 g/l
Boric acid	40 g/l
Nickel chloride	5 g/l
Leveling agent	20 mg/l

and the temperature of the liquid was from 40 to 60°C. The electroforming was carried out by using constant current (Nikka Engineering Co., Ltd.), where current density was 3 A/cm^2 at an early stage and gradually raised up to 4 A/dm^2 and finally to 5 A/dm^2.

Next, the cylindrical mold was pulled up from the electroforming tank and then washed with water, and the inside peripheral surface of the electroforming film was polished to bring its surface roughness to 0.1 mm or less. In this case, the polishing was effected so that the confronted surfaces of the inside periphery of the electroformed film might be parallel to each other, utilizing the outside peripheral surface of the cylindrical mold as a fundamental surface.

A roll base having a diameter of 190 mm was inserted,into the cylindrical mold, and positioning was made so that the central axis of the roll base might be in accord with the temporary central axis of the cylindrical mold, utilizing the outside peripheral surface of the cylindrical mold as the foundation. Afterward, an adhesive (trade name BR Resin; made by Mitsuibishi Gas Chemical Company, Inc.) was poured into the space between the peripheral surface of the roll base and the inside peripheral surface of the electroformed film, and it was then cured.

The roll base on which the electroforming film and the flexible master were fixed was pulled out from the cylindrical mold, and the electroformed film was then separated from the flexible master, thereby obtaining a molding roll.

This molding roll 1 was attached to a molding apparatus shown in Fig. 15, and polycarbonate 153 (trade name Panlite L-1225; made by Teijin Chemicals Co., Ltd.) was then extruded from an extruder 151 (trade name SHT 90; Hitachi Shipbuilding & Engineering Co., Ltd.) to mold a substrate sheet for optical cards having a thickness of 0.4 mm and a width of 30 cm.

With regard to molding conditions in this case, the temperature of a T-die 152 was 300°C, the surface temperature of the molding roll was 150°C, the carrying velocity of the molded resin sheet was 3 m/minute, and the ratio of peripheral speeds of the molding roll 1 and the mirror roll 155 was set to 1:001, and a molding time was 3 hours.

For the transfer accuracy of each preformat pattern-transferred portion on the thus obtained substrate sheet, the section of the pregrooves-transferred portion in a direction vertical to the 9 pregrooves or the sections of the prepits-transferred portion in directions parallel and vertical to the pregrooves were observed by an electronic surface morphology analyzer (trade name ESA-3000; Erionix Co., Ltd.), and then the plane surfaces of the preformat pattern-transferred portion were further observed by an optical microscope (x 400).

As the results of the above-mentioned observation, the occurrence ratio of defects such as breakages and cracks in the vicinity of the pregrooves and the prepits of the substrates for optical cards was evaluated.

The evaluation of the occurrence ratio was made as follows: A substrate having a relief preformat was first prepared, and when even one breakage or crack was present in the vicinity of the relief preformat, the substrate was estimated to be defective. Thus, the occurrence ratio was calculated from the formula

$$A/B \times 100$$

A: the number of the defective relief preformats, and
B: the total number of the prepared relief preformats.

Reference Example 1

The same procedure as in Example 1 was effected except that a flexible master was installed in a cylindrical mold so that a pregroove pattern 91 might be vertical to a peripheral direction as shown in Fig. 10, thereby manufacturing a molding roll, and a substrate sheet for optical cards was molded by the use of the thus manufactured molding roll.

Example 2

The same procedure as in Example 1 was effected except that an angle θ_0 of a surface f to a base in a prepit pattern 92 of a flexible master was 30°, thereby preparing a molding roll, and a substrate sheet for optical cards was molded by the use of the thus prepared molding roll.

Example 3

The same procedure as in Example 1 was effected except that when a chromium film was formed on a glass plate in a matrix formation step, a mixing ratio of nitrogen and oxygen was continuously changed to form the films, thereby preparing the matrixes, and flexible masters were obtained by the use of these matrixes.

In each of the thus obtained flexible masters, the sectional shape of a pregroove pattern in a vertical direction was a reverse trapezoid having $\theta_1 = 55°$, and angles of the surfaces e and f to a base in a prepits pattern were $\theta_2 = 55°$ and $\theta_3 = 55°$, respectively.

This flexible master was fixed on a cylindrical mold so that the pregroove pattern of the flexible master might be parallel to the peripheral direction of the cylindrical mold.

Next, electroforming was carried out in the same manner as in Example 1, and the inside peripheral surface of the resultant electroformed film was then polished in a taper form so that the electroformed film might be fitted on a roll base 71 in a taper form in the sectional shape thereof having d_{71} = 185 mm and d_{72} = 190 mm on the basis of the outside peripheral surface of the cylindrical mold. Afterward, the electroformed film 25 was mounted on the roll base 71 so as to be d_{73} = 205.7 on the basis of the outside peripheral surface of the cylindrical mold, and the roll base having the electroforming film was pulled out from the cylindrical mold. The resultant roll-shaped stamper was then separated from the flexible master and a fixture 72 was inserted between the roll-shaped stamper and the roll base, thereby obtaining a molding roll. In this case, a passage 73 of a hot medium for heating the molding roll was buried in the roll base.

A substrate sheet for optical cards was molded in the same,manner as in Example 1 by the use of this molding roll, and evaluation was then made.

Example 4

The same procedure as in Example 3 was effected except that a flexible master was fixed on a cylindrical mold so that a pregroove pattern of the flexible master might be vertical to the peripheral direction of the cylindrical mold, thereby obtaining a molding roll. A substrate for optical cards was molded by the use of the thus obtained molding roll, and evaluation was then made.

Example 5

An apparatus for manufacturing a substrate sheet for optical cards shown in Fig. 16 was prepared by the use of a molding roll obtained in Example 3.

That is, a polycarbonate sheet having a thickness of 0.4 mm was used as a sheet substrate 164, and an ultraviolet-curing resin layer having a thickness of 40 μm and having the following composition was formed on the surface of the molding roll:

Composition of Ultraviolet-curing Resin

Urethane acrylate	30 parts
Neopentyl glycol-modified trimethylolpropane diacrylate	67 parts
1-hydroxycyclohexyl phenyl ketone	3 parts

A sheet substrate 164 was carried at 2.4 m/ minute, and after the molding roll was brought into close contact with the sheet substrate, the ultraviolet-curing resin layer was irradiated with ultraviolet rays (2 kW high-pressure mercury vapor lamp, 300 mW/cm^2) through the sheet substrate to cure the ultraviolet-curing resin layer and to integrate the resin layer with the substrate sheet. Next, the substrate sheet was released from the molding roll to obtain the substrate sheet for optical cards. The thus obtained substrate sheet was evaluated in the same manner as in Example 1.

The evaluation results of the substrate sheets for optical cards prepared in Examples 1 to 5 and Reference Example 1 are shown in Table 1.

Table 1

	Defect Occurrence Ratio
Example 1	30%
Example 2	4.4%
Example 3	0.01%
Example 4	1.7%
Example 5	0.8%
Reference Example 1	70%

Claims

1. A molding roll having a relief pattern on the peripheral surface thereof which comprises a roll base and a stamper fixed on the peripheral surface of the roll base, said stamper being roll-shaped and seamless.

2. A method for manufacturing a molding roll having a relief pattern on the peripheral surface thereof and comprising a roll base and a roll-shaped and seamless stamper fixed on the peripheral surface of the roll base, said method comprising the steps of:

   a first step of disposing a flexible master having a pattern corresponding to the relief pattern of the molding roll on the surface thereof in a cylindrical mold so that the back surface of the flexible master may be brought into contact with the inside peripheral surface of the cylindrical mold,

   a second step of applying electroforming to the surface of the flexible master to form a roll-shaped stamper thereon,

   a third step of releasing the flexible master having the formed roll-shaped stamper from the cylindrical mold, and then separating the roll-shaped stamper from the flexible master,

   and a step of processing the roll-shaped stamper into the molding roll.

3. The method for manufacturing a molding roll according to Claim 2 wherein the step of processing the roll-shaped stamper into the molding roll comprises a step of polishing the inside peripheral surface of the roll-shaped stamper and a step of fixing the roll-shaped stamper on the roll base.

4. The method for manufacturing a molding roll according to Claim 2 wherein the step of processing the roll-shaped stamper into the molding roll is carried out prior to the third step.

5. The method for manufacturing a molding roll according to Claim 4 wherein the step of processing the roll-shaped stamper into the molding roll is carried out on the basis of the cylindrical mold.

6. The method for manufacturing a molding roll according to Claim 2 wherein the flexible master is formed by a casting process.

7. The method for manufacturing a molding roll according to Claim 3 wherein the roll-shaped stamper is fixed on the roll base with an adhesive.

8. The method for manufacturing a molding roll according to Claim 3 wherein the inside peripheral surface of the roll-shaped stamper is tapered by polishing, and the roll base having a shape corresponding to this taper form is inserted in and fixed to the roll-shaped stamper.

9. A method for manufacturing a molding roll for molding substrate sheets for optical cards having preformat patterns corresponding to striped pregrooves and prepits on the peripheral surface thereof and comprising a roll base and a roll-shaped and seamless stamper fixed on the peripheral surface of the roll base, said method being characterized by comprising the steps of:

a first step of installing a flexible master having a pattern corresponding to the preformat pattern on the surface thereof in a cylindrical mold so that the back surface of the flexible master may be brought into contact with the inside peripheral surface of the cylindrical mold,

a second step of applying electroforming to the surface of the flexible master to form a roll-shaped stamper,

a third step of releasing the flexible master having the formed roll-shaped stamper from the cylindrical mold, and then separating the roll-shaped stamper from the flexible master,

and a step of processing the roll-like stamper into the molding roll.

10. The method for manufacturing a molding roll according to Claim 9 wherein the step of preparing the molding roll by the use of the roll-shaped stamper comprises a step of polishing the inside peripheral surface of the roll-shaped stamper and a step of fixing the roll-like stamper on the roll base.

11. The method for manufacturing a molding roll according to Claim 9 wherein the step of preparing the molding roll by the use of the roll-shaped stamper is carried out prior to the third step.

12. The method for manufacturing a molding roll according to Claim 11 wherein the step of preparing the molding roll by the use of the roll-shaped stamper is carried out on the basis of the cylindrical mold.

13. The method for manufacturing a molding roll according to Claim 9 wherein the flexible master is formed by a casting process.

14. The method for manufacturing a molding roll according to Claim 10 wherein the roll-shaped stamper is fixed on the roll base with an adhesive.

15. The method for manufacturing a molding roll according to Claim 10 wherein the inside peripheral surface of the roll-shaped stamper is tapered by polishing, and the roll base having a shape corresponding to this taper form is inserted in and fixed to the roll-like stamper.

16. The method for manufacturing a molding roll according to Claim 9 wherein in the first step, the flexible master is installed in the cylindrical mold so that the pattern corresponding to the pregrooves of the flexible master may be in parallel with the peripheral direction of the cylindrical mold.

17. The method for manufacturing a molding roll according to Claim 16 wherein the flexible master is used in which the sectional shape of the pattern corresponding to the prepits of the flexible master in a direction parallel to the pattern corresponding to the pregrooves is formed so that confronted walls may form a trapezoid having an angle θ_0 to a base.

18. The method for manufacturing a molding roll according to Claim 16 wherein the flexible master is used in which the sectional shape of the pattern corresponding to the prepits of the flexible master in a direction vertical to the pattern corresponding to the pregrooves is formed so that confronted walls may form a trapezoid having an angle θ_2 to a base and in which the sectional shape of the flexible master in a direction parallel to the pattern corresponding to the pregrooves is formed so that confronted walls may form a trapezoid having an angle θ_3 to a base and in which the sectional shape of the flexible master in a direction

vertical to the pattern corresponding to the pregrooves is formed so that confronted walls may form a trapezoid having an angle θ_1 to a base.

19. The method for manufacturing a molding roll according to Claim 9 wherein in the first step, the flexible master is disposed in the cylindrical mold so that the pattern corresponding to the pregrooves of the flexible master may be vertical to the peripheral direction of the cylindrical mold, and the flexible master is used in which the sectional shape of the pattern corresponding to the prepits of the flexible master in a direction vertical to the pattern corresponding to the pregrooves is formed so that confronted walls may form a trapezoid having an angle θ_2 to a base and in which the sectional shape of the flexible master in a direction parallel to the pattern corresponding to the pregrooves is formed so that confronted walls may form a trapezoid having an angle θ_3 to a base and in which the sectional shape of the flexible master in a direction vertical to the pattern corresponding to the pregrooves is formed so that confronted walls may form a trapezoid having an angle θ_1 to a base.

20. An apparatus for manufacturing substrate sheets for optical recording media which comprises a means for melting and extruding a resin to mold a resin sheet, a molding roll for pressing the resin sheet to transfer a preformat pattern to the surface of the resin sheet, and a mirror roll disposed in the face of the molding roll, said molding roll being provided with a roll base and a roll-shaped and seamless stamper fixed on the peripheral surface of the roll base.

21. An apparatus for manufacturing substrate sheets for optical recording media by which a preformat pattern of a molding roll having the preformat pattern on the peripheral surface thereof is transferred to continuously manufacture the substrate sheets for optical recording media, said apparatus being characterized by comprising:

the molding roll being rotated in a predetermined direction,

a sheet feed means for feeding light-permeable substrate sheets,

a means for forming a photocurable resin composition layer on the peripheral surface of the molding roll,

a means for pressing the photocurable resin composition layer on the peripheral surface of the molding roll against the substrate sheet,

a means which is disposed at a position apart from the pressing position in the rotational direction of the molding roll and which irradiates the photocurable resin composition layer through the substrate sheet with light, and

a means for releasing from the molding roll the resin layer which is integrated with the substrate sheet and to which the preformat pattern is transferred, by irradiation with light from the irradiation means,

said molding roll being provided with a roll base and a roll-shaped and seamless stamper fixed on the peripheral surface of the roll base.

22. A method for making a forming roll which comprises providing a cylindrical master having on an interior surface a pattern corresponding to that of the roll, producing a patterned surface for the roll by electrodepositing material on the interior surface, and separating the deposited material from the master.

23. A method according to claim 22 wherein the master is of a flexible material.

FIG.1A

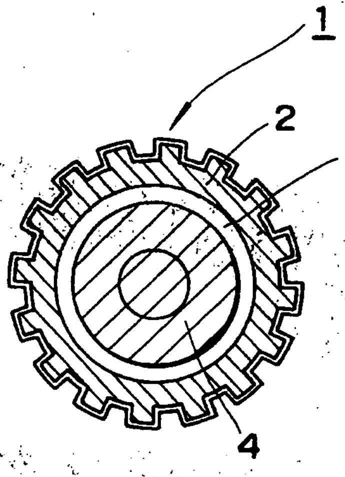


FIG.1B

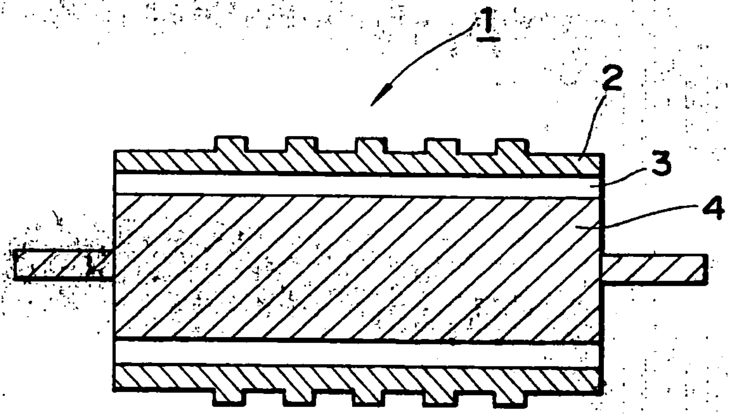


FIG.2A

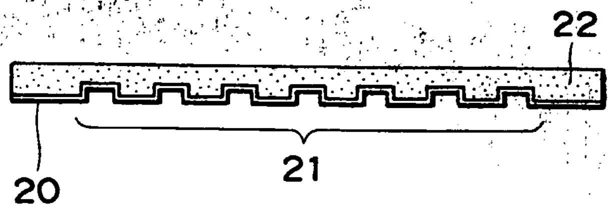


FIG.2B

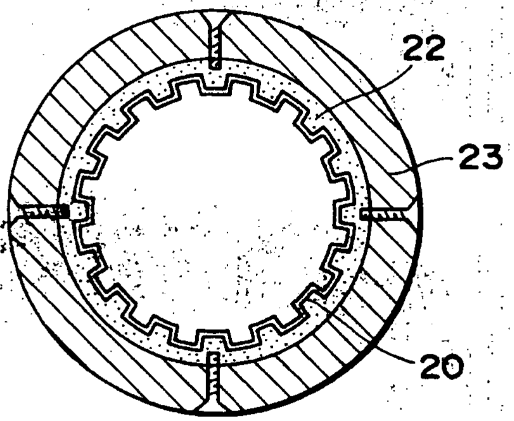


FIG.3A

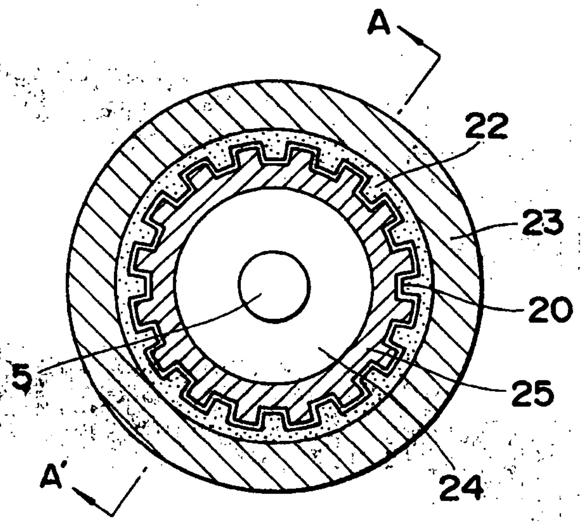


FIG.3B

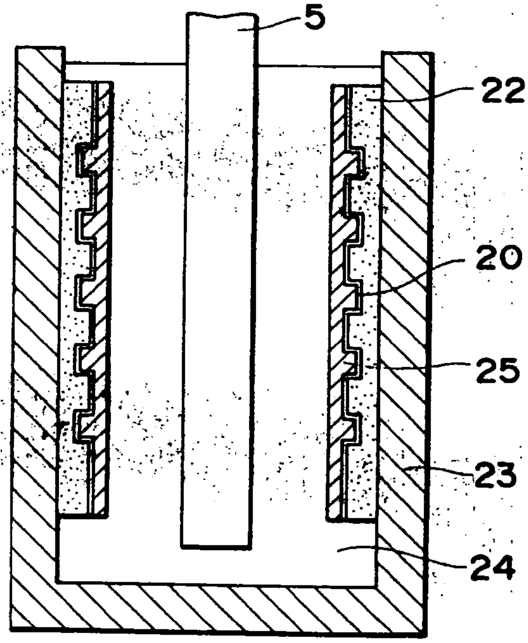


FIG.4

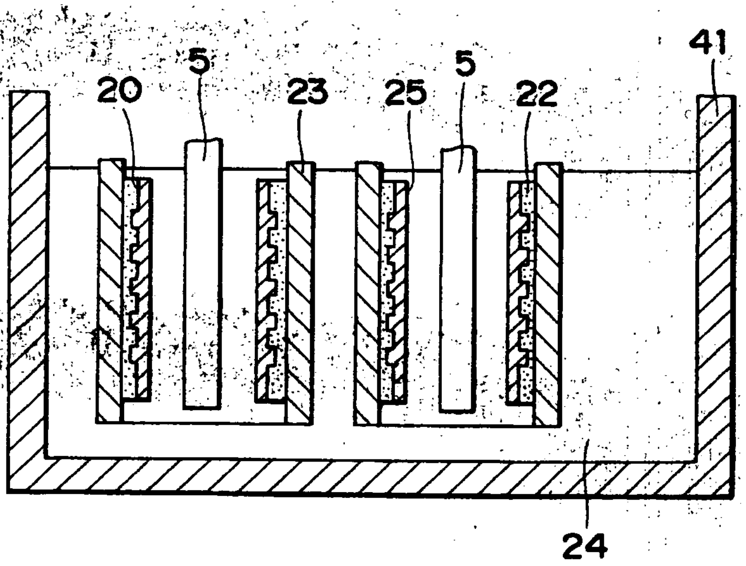


FIG.5A

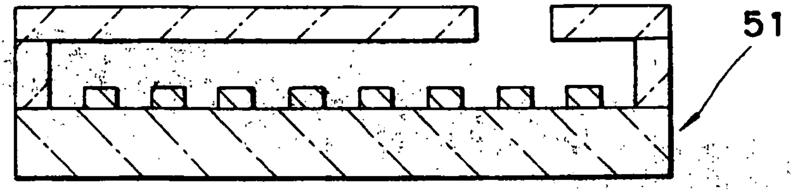


FIG.5B

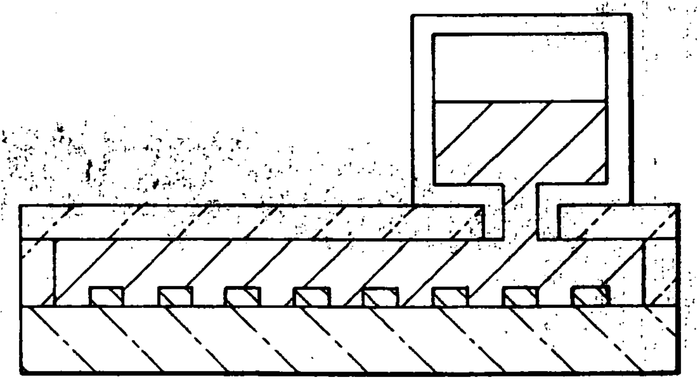


FIG.5C

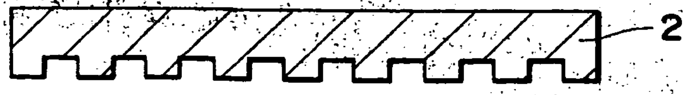


FIG.6

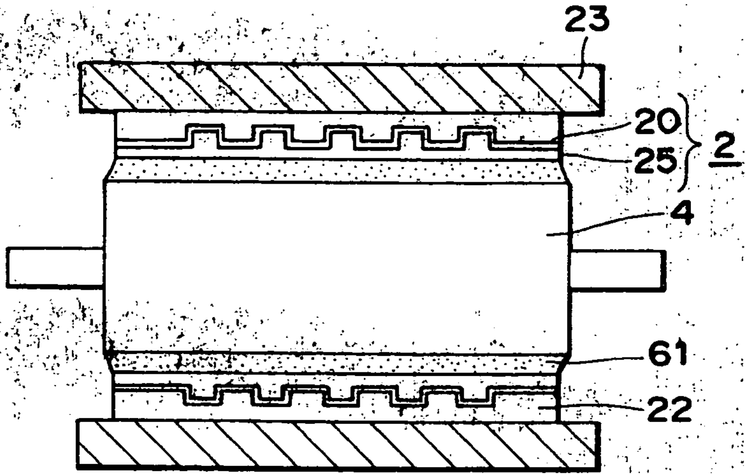


FIG.7A

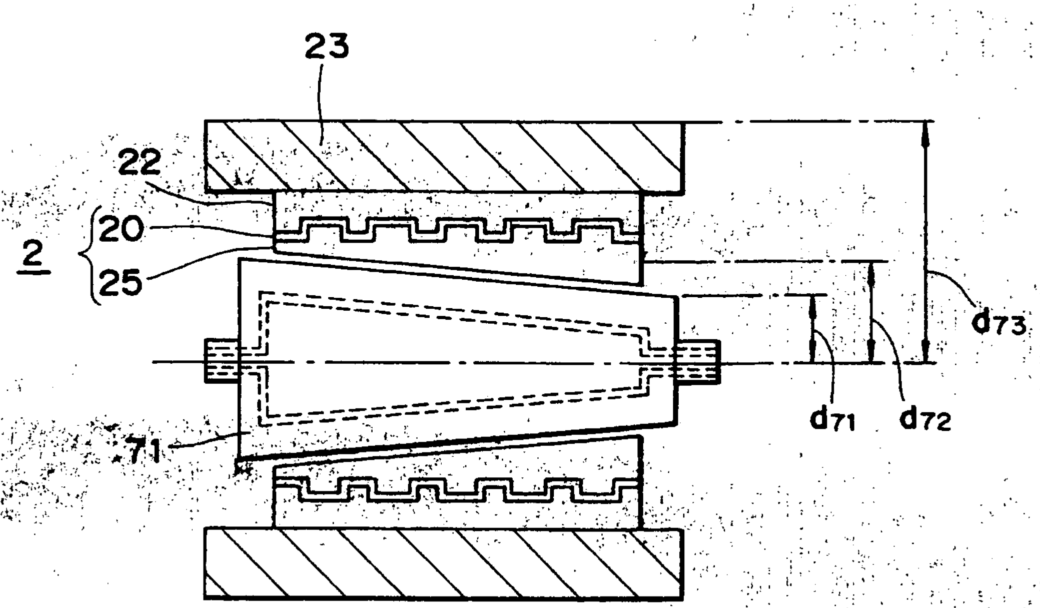


FIG. 7B

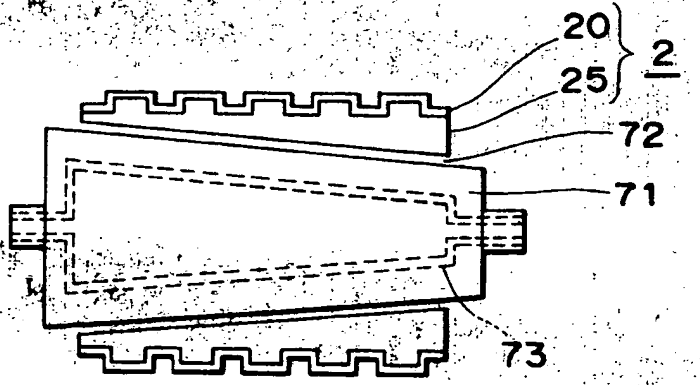


FIG.8

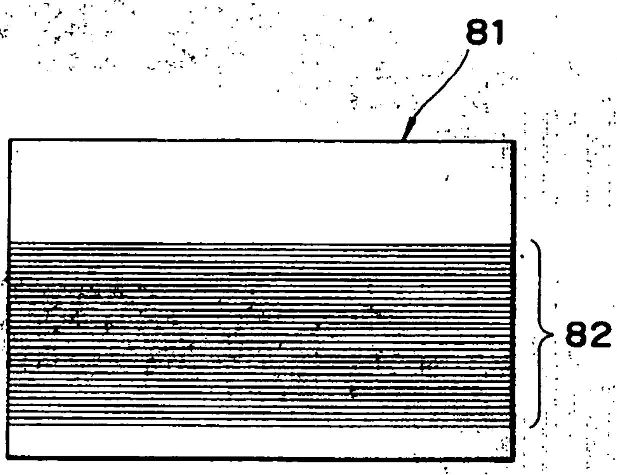


FIG.9

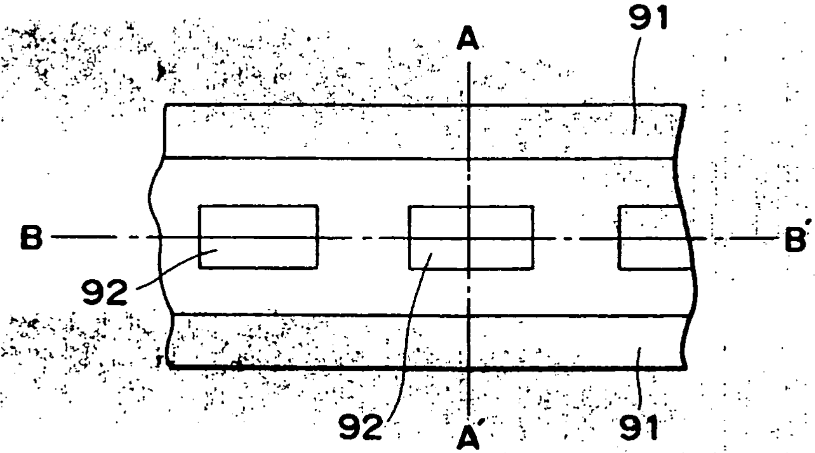


FIG.10

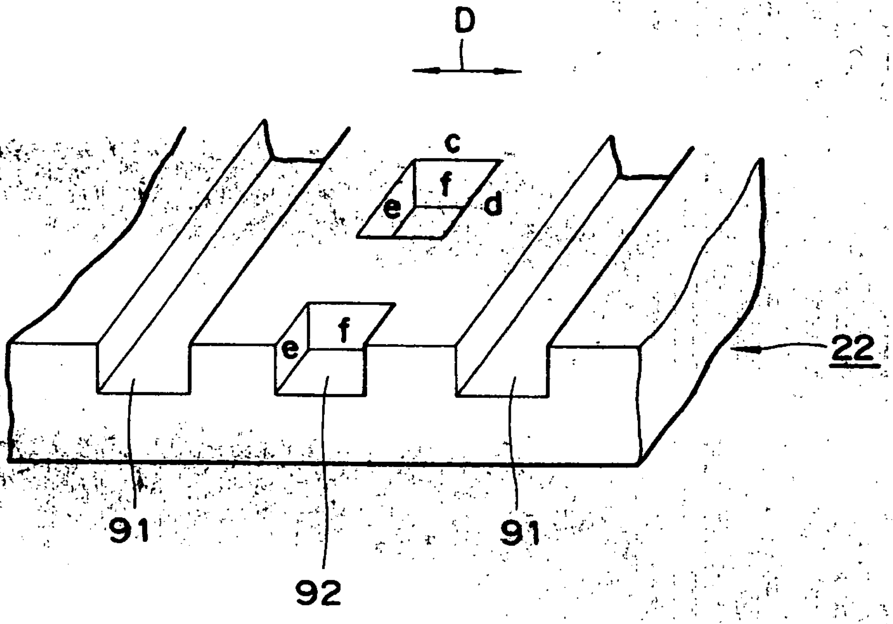


FIG.11

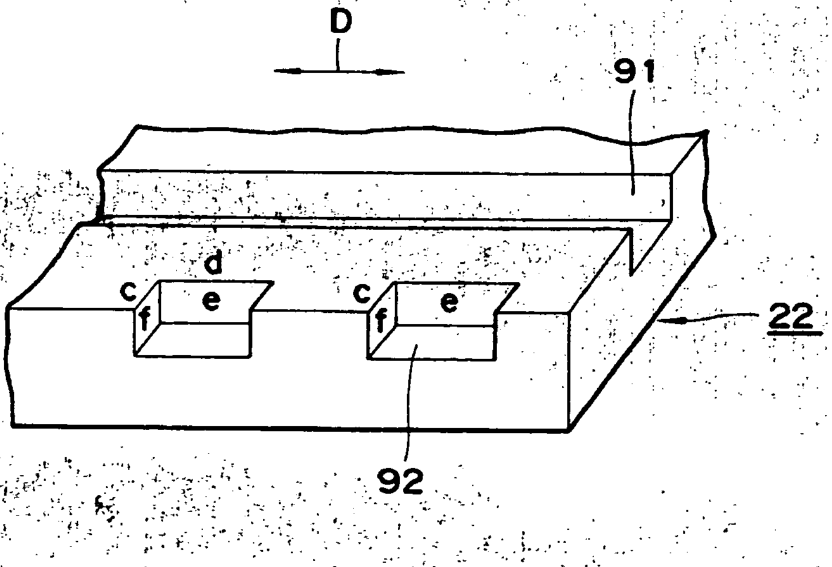


FIG.12

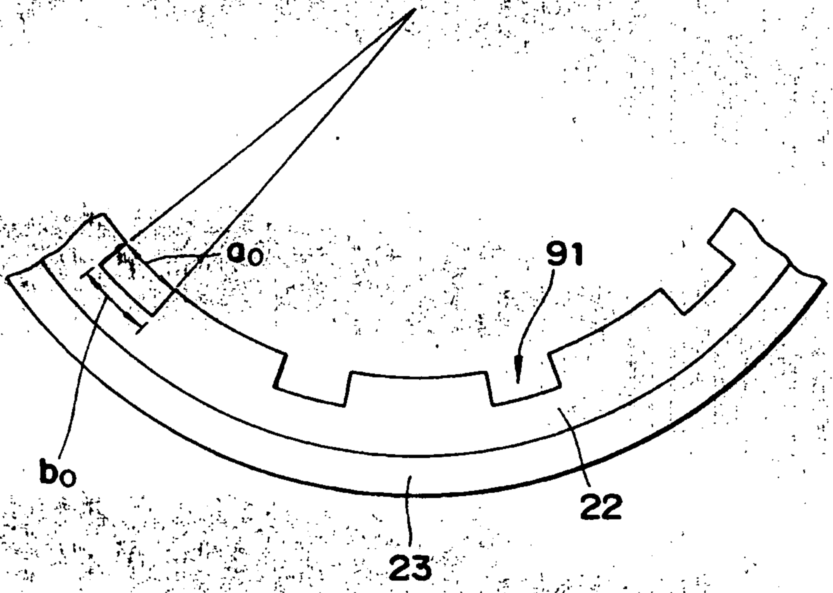


FIG.13

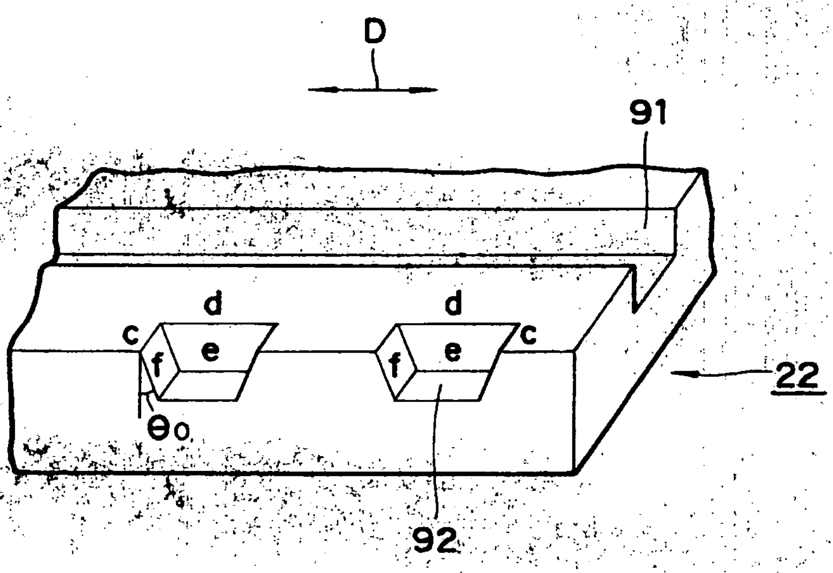


FIG.14A

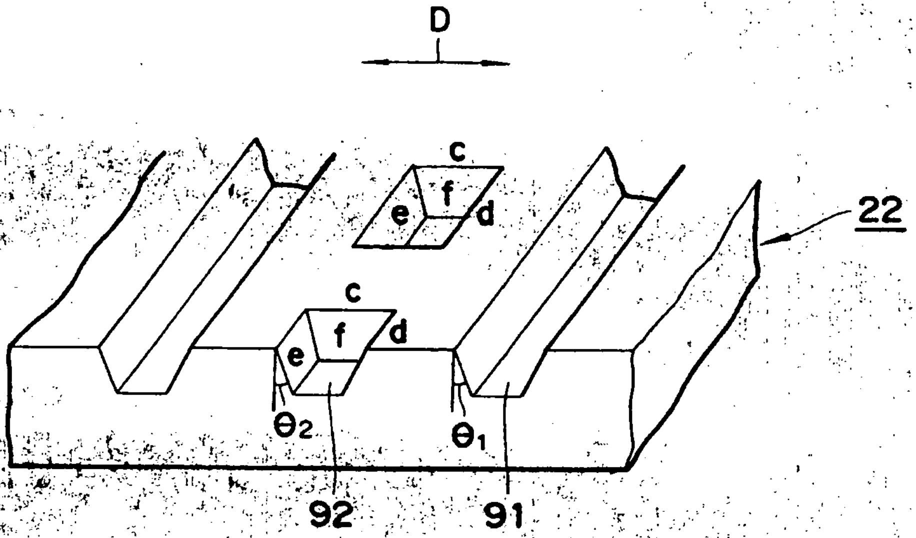


FIG.14B

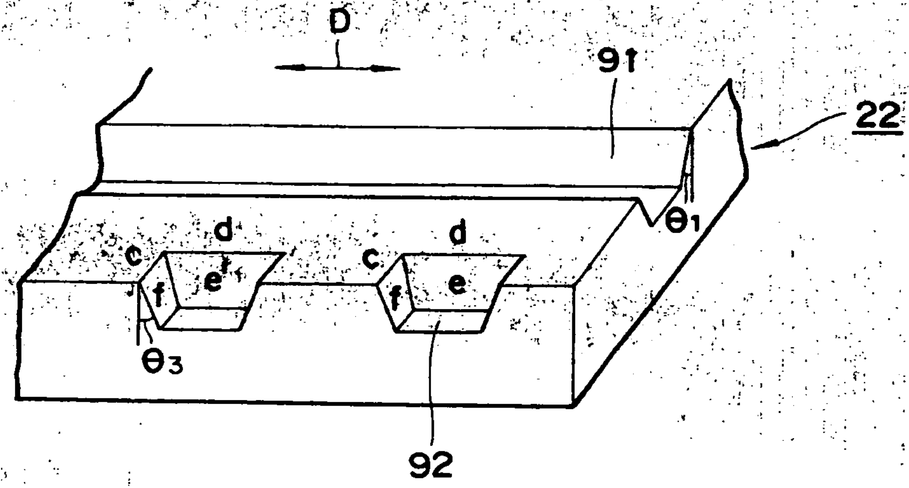


FIG.15

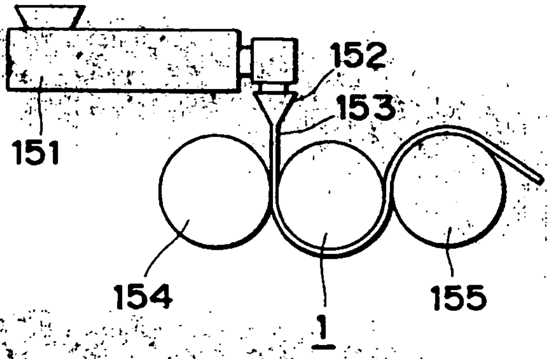


FIG.16